Product: MPS-2 Digital Sensor *(All Configurations)*	Unit Assembly #s: 40854,40855, 40856

Doc. #: 1.02	Document Type: Sensor Specifications

#	Revisions	REV By	Date
1	Initial draft of MPS-2 specifications / integrator's guide	BJW	4.13.11
2	Multiple revisions to specifications to reflect user manual, some revisions to output value ranges	DRC	4.20.11
3	Output waveform capture updated with logic analyzer	DJW	4.21.11
4			
5			
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I. Description of Sensor and Measurements

The MPS-2 digital sensor is designed to measure the water potential (soil suction), and temperature of soil and growing media.

II. Features:

The MPS-2 sensor measures soil water potential and soil temperature. These fundamental measurements are needed for a variety of plant, water flow, and soil mechanical stress studies. By combining these measurements into a single sensor, it allows for more data logger ports to be used for additional environmental measurements. Water potential is obtained by measuring the dielectric permittivity of a solid matrix (porous ceramic disc) through the utilization of capacitance/frequency domain technology. The MPS-2 incorporates high frequency oscillation, allowing the sensor accurate measurements of water potential in any soil or soilless media with minimal salinity and textural effects.

III. Measurement Specifications:

Water Potential

Range: -5kPa to -500 kPa (pF 1.71 to pF 3.71)
Resolution: 0.1 kPa
Accuracy: ±20 kPa from -5 to -100 kPa,
*See user manual for more information regard higher kPa accuracies

Temperature

Range: -40°C to 50°C
Resolution: 0.1°C
Accuracy: ±1°C

General

Survival Environment: -40°C to 60°C, 0 to 100% RH
Operating Temperature: 0°C to 50°C (no water potential measurement below 0°C)
Power requirements: 3.6 - 15 VDC, 0.03 mA quiescent, 10 mA max during 150 ms measurement
Dimensions: 9.6 cm (l) x 3.5 cm (w) x 1.5 cm (d)
Sensor diameter: 3.2 cm
Dielectric Measurement Frequency: 70 MHz
Measurement Time: 150 ms (milliseconds)
Output: RS232 (TTL) with 3.6 volt levels or SDI-12 communication protocol
Connector types: 3.5 mm (stereo) plug or stripped & tinned lead wires (3)
Cable Length: 5m standard; custom cable length available upon request

Input / Output Circuitry

A single line is used for both transmit and receive. A 10 uH inductor and a 510 ohm resistor are in series with the RXD/TXD line on the microprocessor with a 220 pF capacitor to ground. The resistor and capacitor provide input protection. The inductor minimizes RF interference. See Figure 1 for an equivalent circuit diagram.

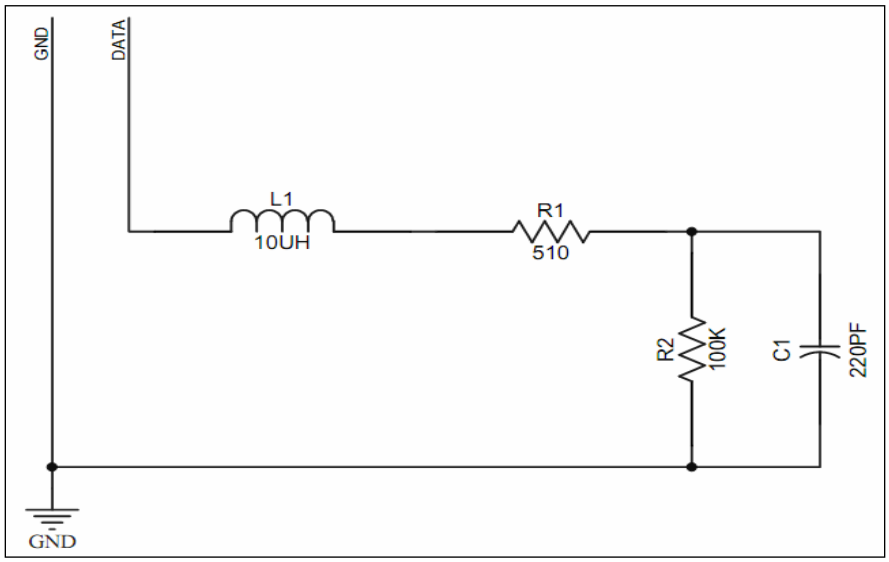


Figure 1. Equivalent Circuit Diagram. If using multiple sensors on a bus, you may use the equivalent circuit to simulate the load of additional sensors (up to 62) on a single SDI-12 line.

Sensor Excitation

The sensor connects through a 3 wire cable with a stereo connector or bare wire interface. The three connections are Excitation, Ground, and Serial Out (Data). The connector tip (white wire) is Excitation, the connector base (shield) is ground, and the intermediate ring (red wire) is Serial Out (see Figure 2 below for stereo jack signal diagram).

Figure 2. Stereo Jack Signal Diagram The signals from base to tip ground, serial out, and power.

The excitation is 3.6 to 15 volts. Current drain during the water potential measurement (approximately 10 ms in duration) can be as high as 10 mA. After data transmission, the sensor will pull around 3mA for about 6 seconds. It will then go into a sleep state and draw around 30uA, until a SDI-12 break command is received. Be sure that the selected power supply can provide this current without being pulled below the 3.6 V level. If all sensors are excited at the same time, all of them will draw 10mA for 10ms. The system will need to source enough current to supply the number of sensors in the system (up to 62), x, times 10mA (Total current = x * 10mA).

TTL Communication

The serial out uses 1200 baud asynchronous CMOS with 8 data bits, no parity, and one stop bit. The voltage levels are 0 - 3.6 V and the logic levels are TTL (active low). Each data byte consists of a start bit (low), 8 data bits (least significant bit first), and a stop bit (high), see Figure 3 and 4 for a serial stream example.

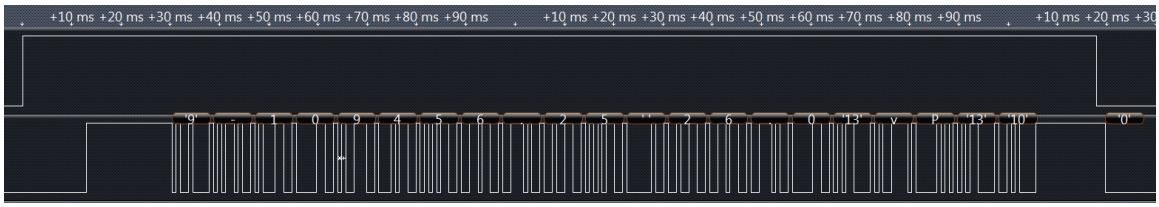


Figure 3. Excitation and serial output stream. Output levels are not absolute. Both excitation and output are zero initially. Approximately 40 ms after the excitation goes high the serial out line goes high. It stays high for 15 ms, and then goes low for the start bit of the serial stream. Twelve characters are shown: 100 100 100/r. When the carriage return character is received the excitation is shut off.

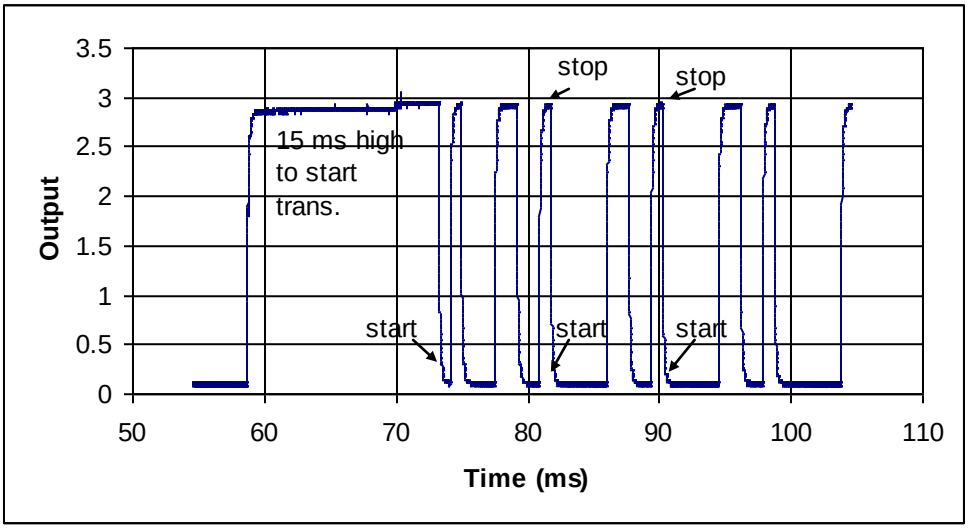


Figure 3. Expansion of first few bits of serial stream from Fig. 1 showing the start and stop bits and the data bits. Baud rate is 1200, so one byte (8 data bits plus start and stop) takes 0.833 ms. Bytes are transmitted lsb (least significant bit) first, so the first character, 10001100 represents 00110001 or 0x31 which is ASCII 1. The next character is 00001100 which is 0x30 or ASCII 0.

TTL Format Description

The data string output by the sensor should be in a format similar to the one below:

```
<tab>-34.8 22.3<cr>yN<cr><lf>
```

Section	Description
<tab>	Tab character (0x09) signaling the start of the transmission
-34.8	Water potential in kPa. Values range approximately from -7 kPa to -110,000 kPa. *Note: in the case of an error, water potential will output an error value of -9999. The water potential calculation adds a small offset for real water potential values that calculate to -9999 so that the error value is a unique case.*
22.3	Temperature. This number is the temperature of the sensor in degrees Celsius. *Note: In the case of an error, temperature will output an error value of*

	-9999.
<cr>	This carriage return character signals the end of the measurement string and start of the meta data string.

Everything below is this line is meta data:

y	Sensor Type. This character is used to indicate the sensor type. y is used for the MPS-2 sensor.
N	Checksum. This one character checksum is used in our instruments to ensure that the data transmitted are valid. The checksum is used for sections listed above: "<tab>-34.8 22.3<cr>y See the following function for an example of how to implement the checksum algorithm in C.
<cr><lf>	The carriage return (0x0d) and line feed (0x0a) are used to signal the end of the meta data section and the end of the transmission.

Here is an example of how to calculate the checksum (crc) in C. In this case, the string passed to the function would be: "<tab>-34.8 22.3<cr>y" and the returning value would be the character 'N'.

```
char CalculateChecksum(char * Response){
    int length, sum = 0, i, crc;

    // Finding the length of the response string
    length = strlen(Response);

    // Adding characters in the response together
    for( i = 0; i < length; i++ )
        sum += Response[i];

    // Converting checksum to a printable character
    crc = sum % 64 + 32;

    return crc;
}
```

TTL Typical Outputs

Typical output while the sensor is suspended in air 20°C will be *approximately*:
-100000 kPa and 20.0 °C.
If the sensor is fully saturated in 20C DI water, the outputs will be *approximately*:
-8 kPa and 20.0 °C.

SDI-12 Communication

When power is applied to the probe it transmits the TTL data values as previously discussed. It then enters a low power state waiting for input. The commands it

recognizes follow the SDI-12 protocol (see http://www.sdi-12.org for detailed information on the SDI-12 protocol). Communication is at 1200 baud, but logic levels are opposite to those for the initial transmission (start bit high; stop bit low) to conform to SDI-12 protocol. A communication starts with a SDI-12 break or any transmitted character. This "wakes" the sensor. No activity on the communication line for approximately 10 s returns it to sleep mode (30 uA current drain). Since there is only one data line which is used for both transmit and receive, the host must transmit its message and then quickly switch to receive mode to monitor the response. All commands are of the form <address><command><parameters>! The "!" is always the termination character for every SDI-12 command. Multiple device addresses are allowed so several probes can be connected to one port if they have different addresses, and each can be addressed separately. The "?" can be used in place of an address, in which case all devices connected to the port will respond.

SDI-12 Format Description

The D0 data string output by the sensor should be in a format similar to the one below:

`<addr>-34.8+22.3<cr><lf>`

Section	Description
`<addr>`	Sensor SDI-12 Address. A one character long SDI-12 address for the sensor. It can be any alphanumeric value (0-9, a-z, A-Z), 0 is the default
`-34.8`	Water potential in kPa. Values range approximately from -7 kPa to -110,000 kPa. *Note: in the case of an error, water potential will output an error value of -9999. The water potential calculation adds a small offset for real water potential values that calculate to -9999 so that the error value is a unique case.*
`22.3`	Temperature. This number is the temperature of the sensor in degrees Celsius. *Note: In the case of an error, temperature will output an error value of -9999.*
`<cr><lf>`	This carriage return line feed combination signals the end of the measurement string

Some Commonly Used SDI-12 Commands:

Command	Description
A<new address>	change the sensor address; an address can be an integer 0..9 or letter, A..Z, a..z
I	returns probe ID
M	measure probe values
D0	return measured values

SDI-12 Examples:
The characters in bold are what was sent to the sensor.

1I!113DECAGON MPS2 108
Identify sensor with address of 1; Return: Sensor Address(1), SDI12 Version (13), COMPANY (DECAGON), SENSOR TYPE (MPS2), SENSOR VERSION (108)

1M!10012
Measure parameters of sensor with address of 1; Return: sensor address is 1, data are ready in 001 ms, 2 values will be sent

1D0!1-82.6+21.8
Send the values; Return: sensor address is 1, -82.6 kPa for water potential, 21.8 °C for temperature

?!0
This returns the sensor address; Return: sensor address is 0

0A1!1
Change the sensor address to 1; Starting address is 0. Return: new sensor address is 1

SDI-12 Compliance:
Decagon's SDI-12 sensors recognize all SDI-12 commands outlined in Version 1.3 of the SDI-12 Protocol (see http://www.sdi-12.org for more detailed information).

Here is a list of differences between the SDI-12 standard and Decagon's SDI-12 sensors:

- Upon excitation, a TTL string is printed prior to enabling SDI-12 (takes around 75ms).
- Parity Bits are ignored.
- R & RC Commands return a reading after about 50ms.
- Timeout / Power Down is around 5 seconds instead of 100ms.
- After Timeout / Power Down, sensors may respond to a break that's less than 6.5 ms.

SDI-12 Diagrams:

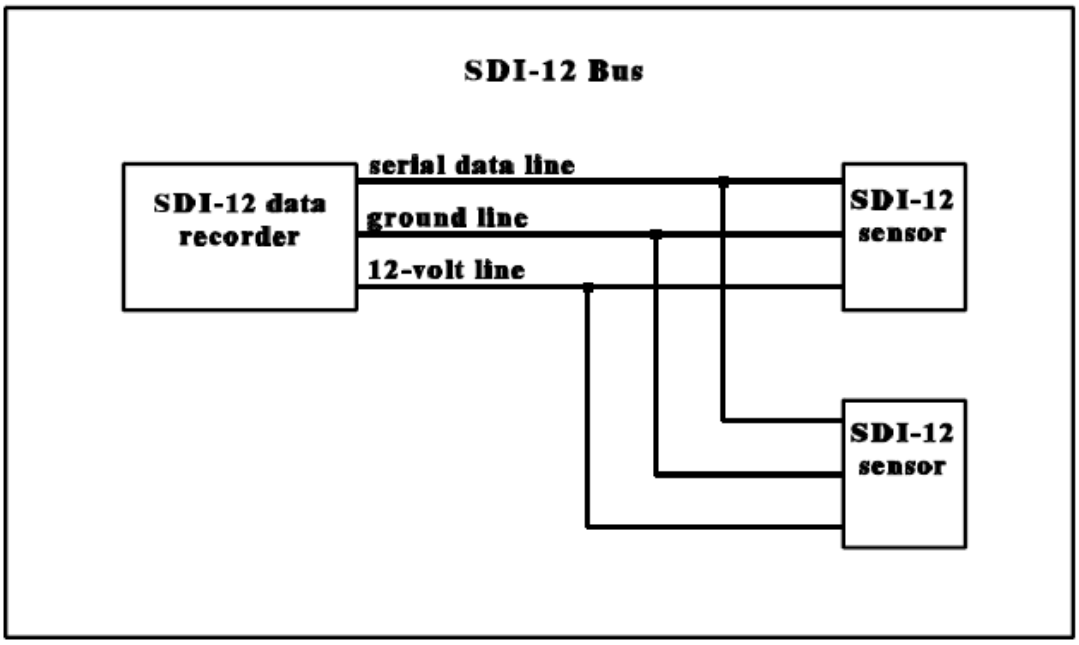


Figure 1. The SDI-12 Bus

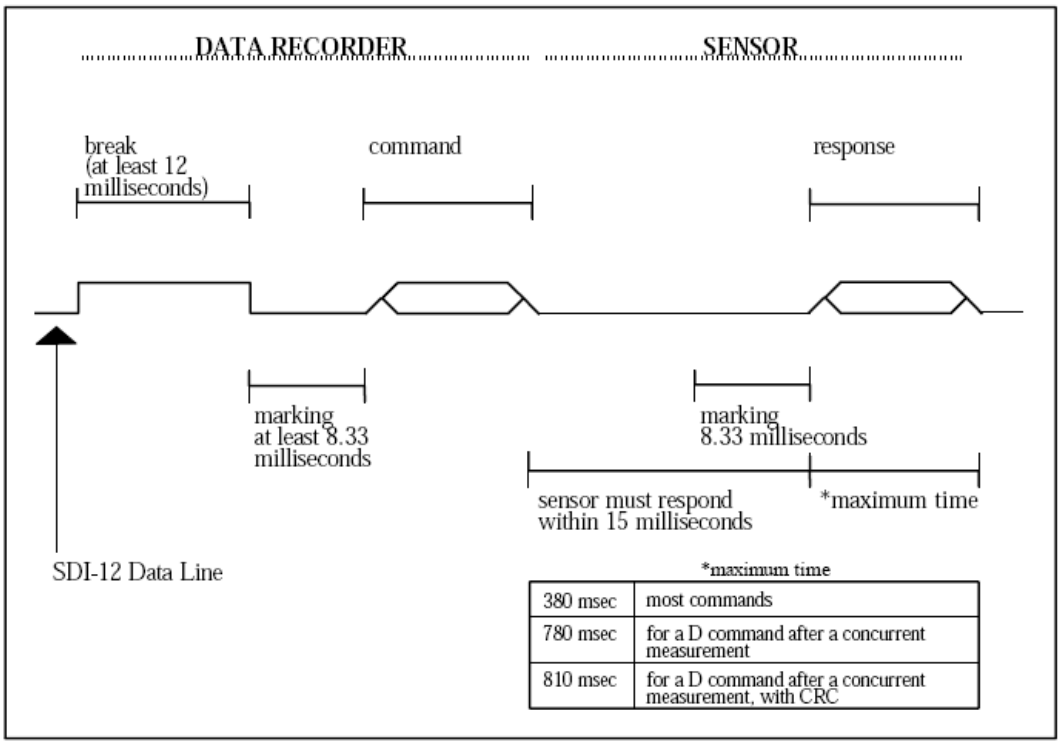
All sensors must have a unique address. At most 62 sensors can be connected to a single bus.

Condition	Binary state	Voltage range
marking	1	-0.5 to 1.0 volts
spacing	0	3.5 to 5.5 volts
transition	undefined	1.0 to 3.5 volts

Table 1. Logic and voltage levels for serial data

1 start bit
7 data bits, least significant bit transmitted first
1 parity bit, even parity
1 stop bit

Table 2. SDI-12 byte frame format



*maximum time

380 msec	most commands
780 msec	for a D command after a concurrent measurement
810 msec	for a D command after a concurrent measurement, with CRC

Figure 3. SDI-12 Timing